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Design and Simulation of Soot Blower Lance Tube

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ABSTRACT

Dependability on soot-blower lance tube design and thickness is very significant for the cleanliness of tube bank boiler in Company A. Major problem in soot blowers was the bending of the lance tube due to external forces, material weakness, and improper balancing. The objectives of this research are to design and simulate as well as to study the heat transfer characteristics of soot blower lance tube. This research starts with 3D geometry modelling, then set up for simulation with Computational Fluid Dynamic (CFD) software (COMSOL Multiphysics) to analyse the heat transfer characteristics. The results for the CFD simulation are velocity and temperature distributions along the soot blower lance tube. The most efficient model was three joint lance tube (3 thickness tube), (11mm (3m long), 7mm (3m long), 5mm (3.2m long)). Then, the most efficient nozzle diameter was 30mm and lastly, the most efficient number of the nozzle was three nozzle holes. The Finite Element Analysis (FEA) shows these models produced high-velocity distribution and low-temperature distribution.

1. Introduction

Boiler is one of the coals fired power plant's core pieces of equipment, which mainly carries out energy transfer by heat transfer. So, soot deposition on the heat transfer surface would reduce the heat transfer effect of the heat transfer surface of the boiler, leading to a reduction in heat transfer efficiency. A soot blower uses a medium to eliminate ash deposition on the heated air sheet, such as steam, sound waves, gas etc.

Fatigue and creep usually found on soot blower lance tube. The bending of the lance tube was the major problem in soot blowers. Among the reason for the bending are due to external forces, material weakness, and improper balancing (Gowshikan 2014). It is more expensive to purchase the

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new equipment compared to doing proven reverse engineering. So, this study is being carried to optimize the function of lance tube with using Computational Fluid Dynamic (CFD) method.

CFD is a constantly emerging study of numerically solving fluid motion equations to produce accurate calculations and interpretation of fluid flow phenomena. When used properly, CFD is also suitable for parametric experiments or flow- investigations that would otherwise be impracticable or impractical by purely theoretical or experimental activities (Hu 2012).

Nevertheless, Finite Element Analysis (FEA) is a dominant method of computation in science and engineering. It is a numerical method that can be used to find solutions to some engineering problems, including steady, transient, linear or non-linear problems (Chakrabarty 2016).

2. Methodology

2.1 Construction of lance tube model

Seven 9.2m length, nickle alloy lance tube models were constructed using SolidWorks® (Dassault Systèmes SE, France) with various parameters (**Table 1**). The models were subjected to heat transfer simulation using Comsol Multiphysics® (Comsol Inc., Sweden). Steam parameters used are tabulated in

Table 2.

Table 1
Parameter of lance tube models used for validation

Model	Diameter (mm)		Nozzle	
	Inner	Outer	Diameter (mm)	No. of nozzle
1	85(9.2m)	90	40	2
2	83(4m), 85(5.2m)	90	40	2
3	79(3m), 83(3m), 85(3.2m)	90	40	2
4	79(3m), 83(3m), 85(3.2m)	90	30	2
5	79(3m), 83(3m), 85(3.2m)	90	50	2
6	79(3m), 83(3m), 85(3.2m)	90	40	3
7	79(3m), 83(3m), 85(3.2m)	90	40	4

Table 2
The operational parameter of soot-blower.

Properties	Dimension
speed (mm/s)	30.9
steam flow (kg/s)	2.15
temperature steam jet inlet (K)	623
steam density (P=15.1 kg/cm2; T=350 °C)(kg/m3)	5.3591
Specific Heat, Cp (T=350 °C) (kJ/kg.K)	2.5

The computational simulation of the soot-blower models was conducted to determine the thermal properties in terms of its temperature and velocity distribution. Joule heating and thermal expansion multiphysics were implemented. The method facilitated thermal merging, electrical and structural analysis automatically. Linear dimension of the material and the change in temperature was related by the linear thermal expansion coefficient. Each degree change in temperature is a fractional change in length. Suitable boundary conditions for heat transfer were set as follows;

$$q_o = h(T_{ext} - T) \quad \text{(Eq. 1)}$$

Where h is the heat transfer coefficient.

Thermal insulation determines the insulation boundary condition for heat transfer interfaces as follows;

$$-n(-k\nabla T) = 0 \quad \text{(Eq. 2)}$$

3. Results and discussion

3.1 Model of soot blower lance tube

Figure 1 shows the 3D geometry model of the lance tube that was designed using Solid Works software. There are seven variants of the model in total that different in their thickness, nozzle diameter and nozzle hole. After completing the modelling process in Solid Work software, the model will be imported to COMSOL Multiphysics software. Then, defining boundary conditions, defining material, meshing process and computation of study. Meshing is an integral part of the simulation process of engineering in which complex geometries are split into simple elements that can be used as discrete local approximations of the larger domain. The mesh affects the accuracy, convergence and speed of the simulation.

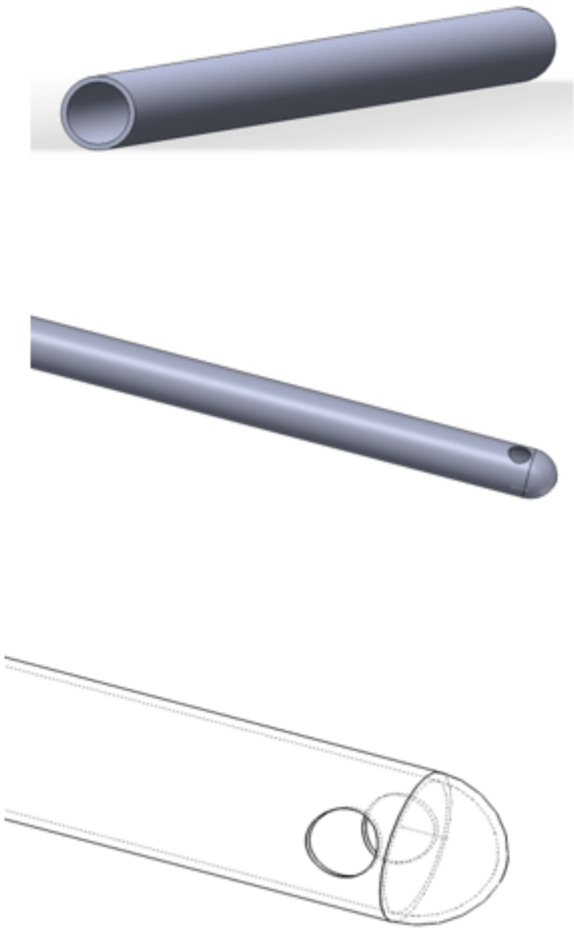


Fig. 1. 3D Geometry of Soot Blower Lance Tube

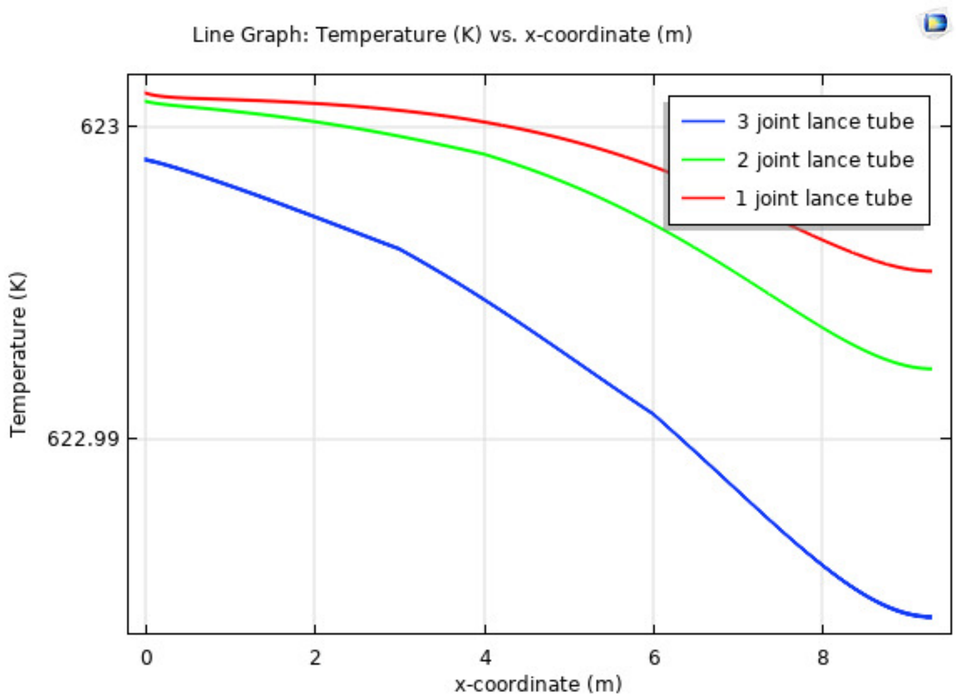
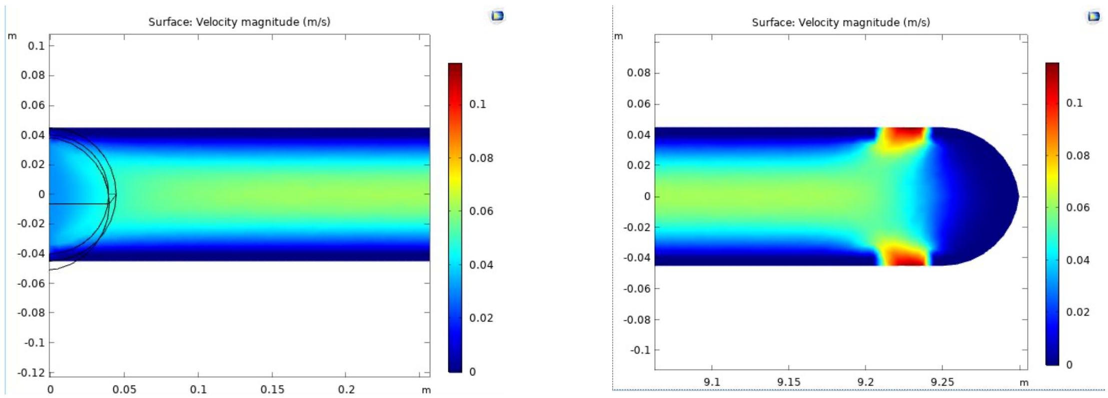


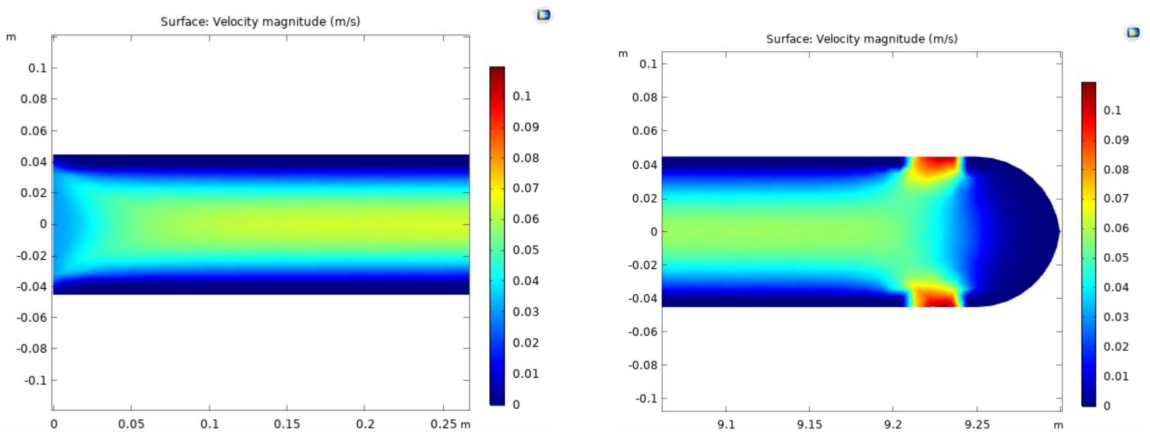
Fig. 2. Temperature Distribution on Lance Tube

Figure 2 shows the temperature distribution along the lance tube in x-coordinate. Based on the graph, we can see that the highest temperature distribution goes to model 1 or 1 joint lance tube (1 thickness tube), (5mm (9.2m long)). Then, the second highest is model 2 or 2 joint lance tube (2 thickness tube), (7mm (4m long), 5mm (5.2m long)). Lastly, the lowest temperature distribution goes to model 3 or 3 joint lance tube (3 thickness tube), (11mm (3m long), 7mm (3m long), 5mm (3.2m long)). As we can see, the different number of joint and thickness affect the temperature distribution on each lance tube. This behaviour is similar to those reported in previous study [40].

Model 1



Model 2



Model 3

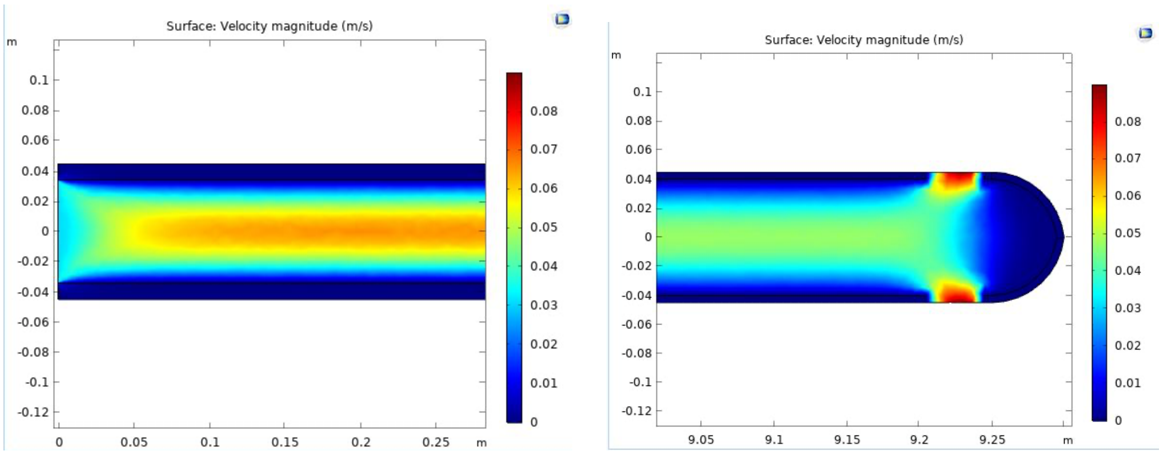


Fig. 3. Velocity distribution of Model 1, 2 and 3

Figure 3 shows the velocity distribution for Model 1, 2 and 3 with different joint and thickness. From the colour scale of velocity, we can see that the highest velocity distribution goes to Model 3 which is 3 joint lance tube (3 thickness tube), (11mm (3m long), 7mm (3m long), 5mm (3.2m long)). Then, the second-highest goes to model 2 which is 2 joint lance tube (2 thickness tube), (7mm (4m long), 5mm (5.2m long)). Lastly, the lowest velocity distribution is model 1 or 1 joint lance tube (1 thickness tube), (5mm (9.2m long)). We can see that the different in number of joint and thickness affect the velocity distribution on lance tube.

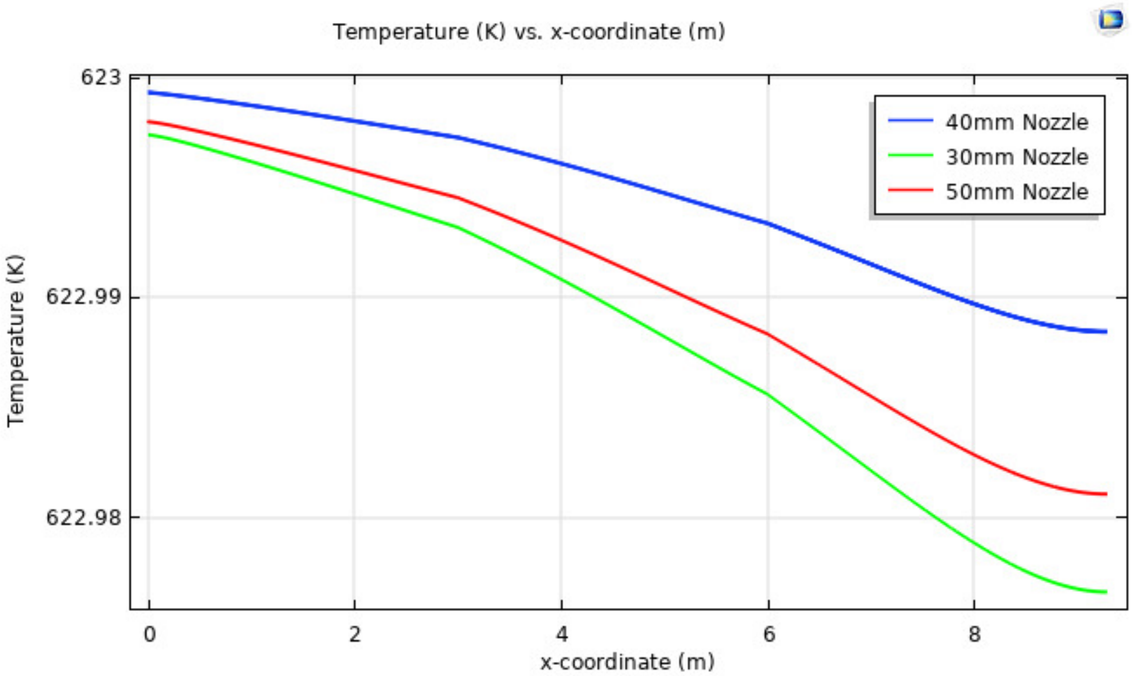
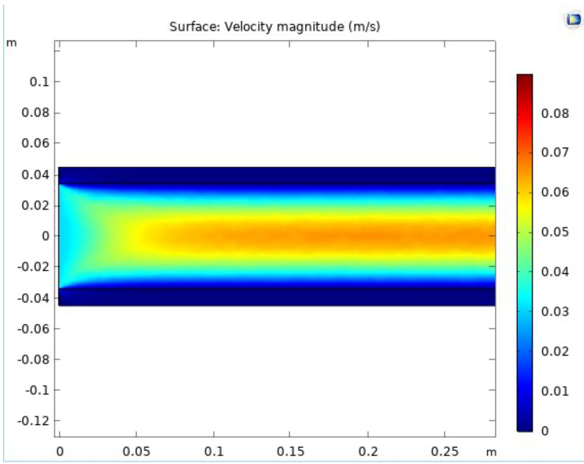
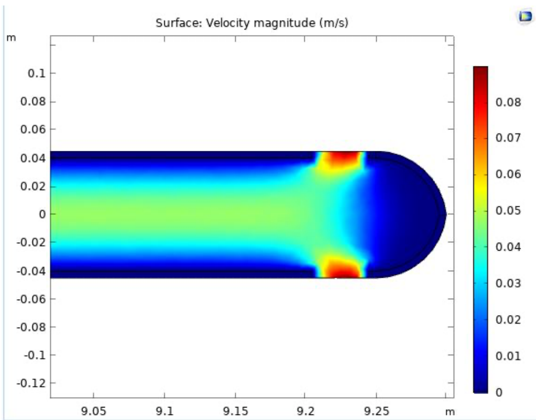


Fig. 4. Temperature Distribution on Lance Tube with different nozzle diameter

Figure 4 above shows the temperature distribution along the soot blower lance tube in the x-direction. Based on the graph, we can see that the highest temperature distribution goes to 40mm nozzle diameter. Then, the second-highest goes to 50mm nozzle diameter. Lastly, the lowest temperature distribution goes to 30mm nozzle diameter. As we can see, the temperature distribution also affected by the diameter of nozzle hole.

Model 3





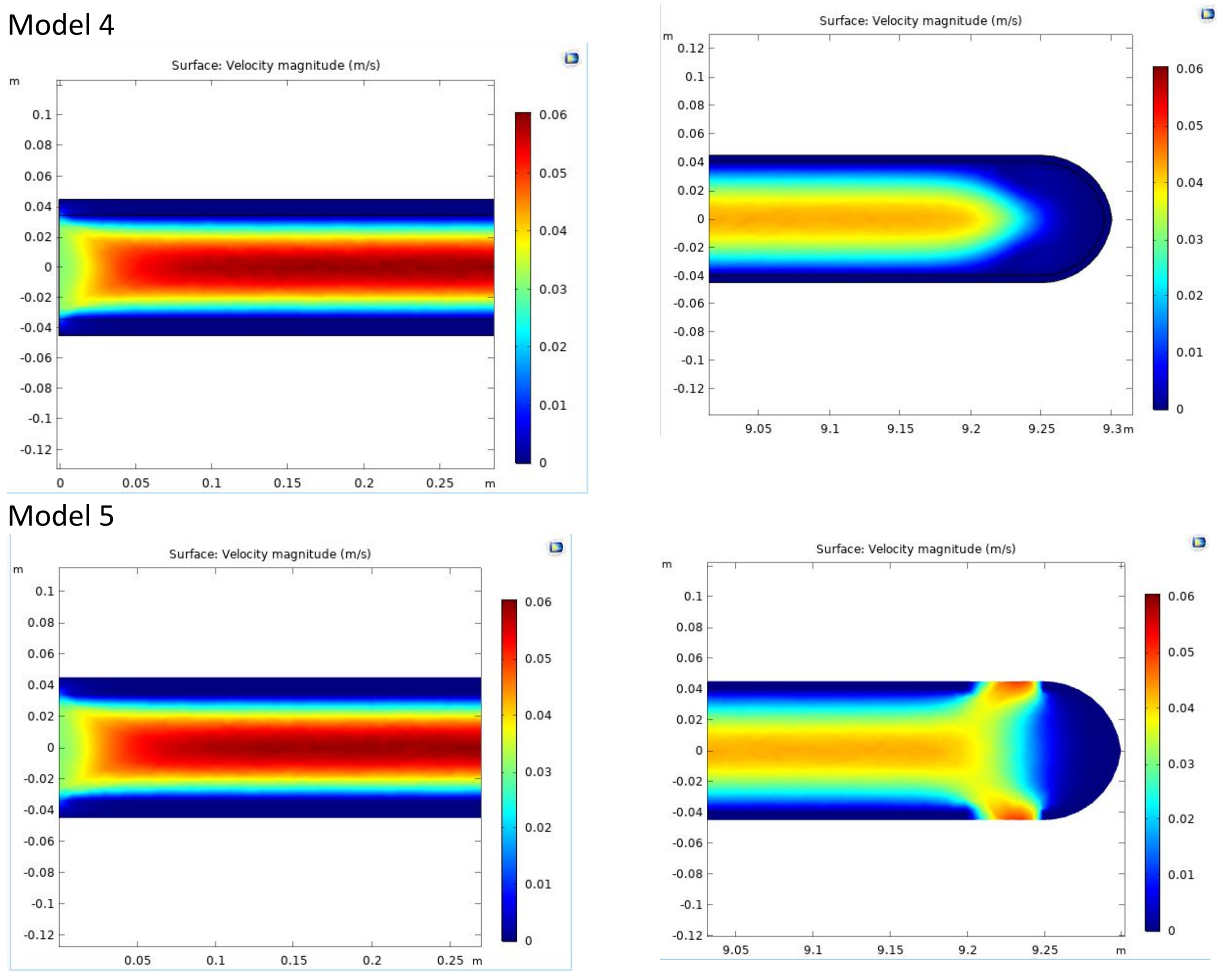


Fig. 5. Velocity Distribution of Model 3, 4 and 5

Figure 5 shows the velocity distribution on the Model 3, 4 and 5 lance tube in their start and end. The models are different in nozzle diameter. From the colour scale of velocity, we can see that the highest velocity distribution goes to Model 4 which is 30mm diameter. Then, the second-highest goes to model 5 which is 50mm diameter. Lastly, the lowest velocity distribution is model 3 which is 40mm diameter. So, the different of nozzle diameter also affect the velocity distribution of lance tube.

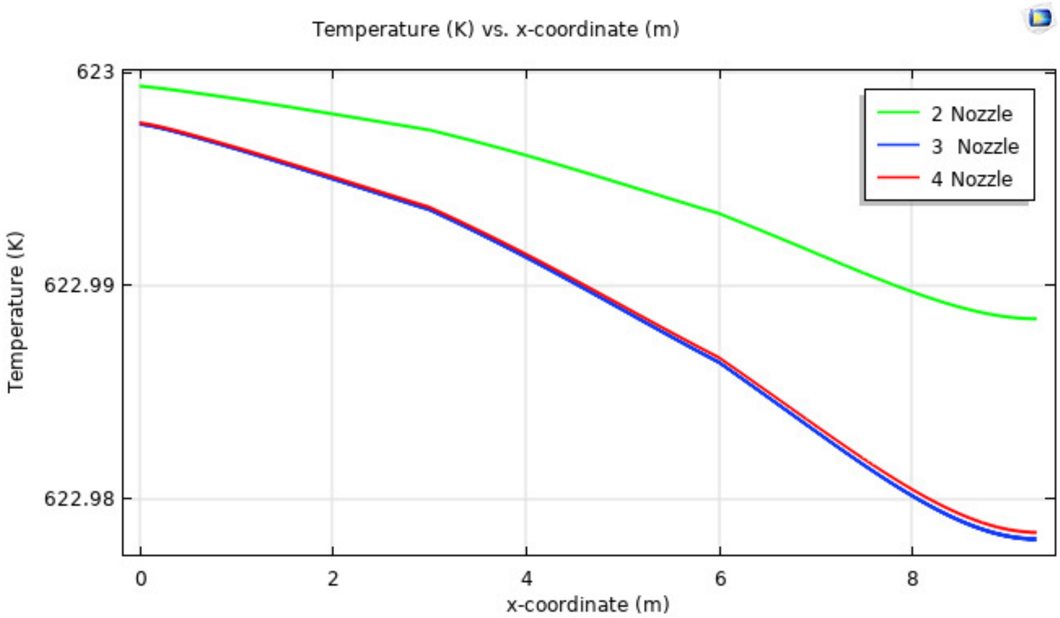
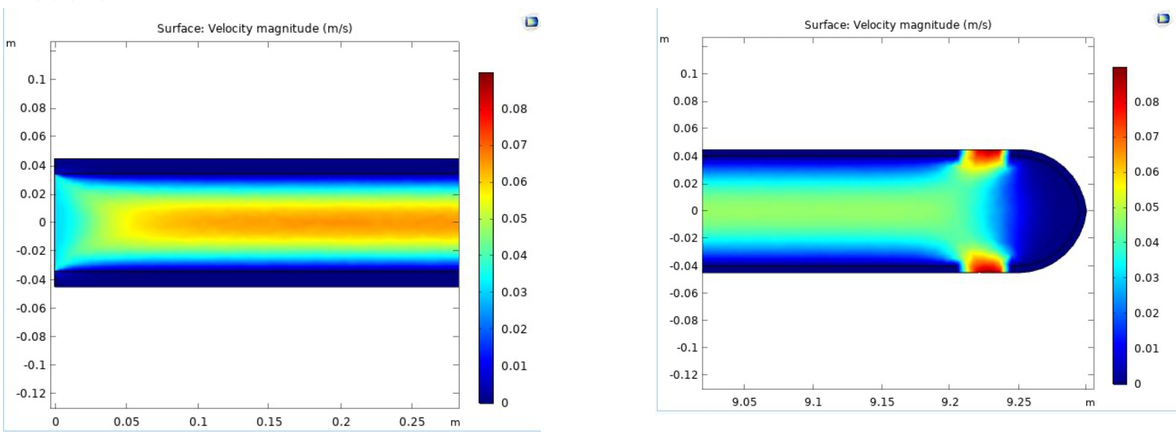


Fig. 6. Temperature Distribution on Lance Tube with Different Number of Nozzle

Figure 6 shows the temperature distribution along the lance tube in x-coordinate. From the graph, we can see the highest temperature distribution goes to 2 nozzle lance tube. Next, the second-highest goes to 4 nozzle lance tube. Lastly the lowest temperature distribution in 3 nozzle lance tube. There is just a bit different between 4 nozzle lance tube and 3 nozzle lance tube. We can see that when the number of nozzle was added from two to three and four, the temperature has been lower.

Model 3



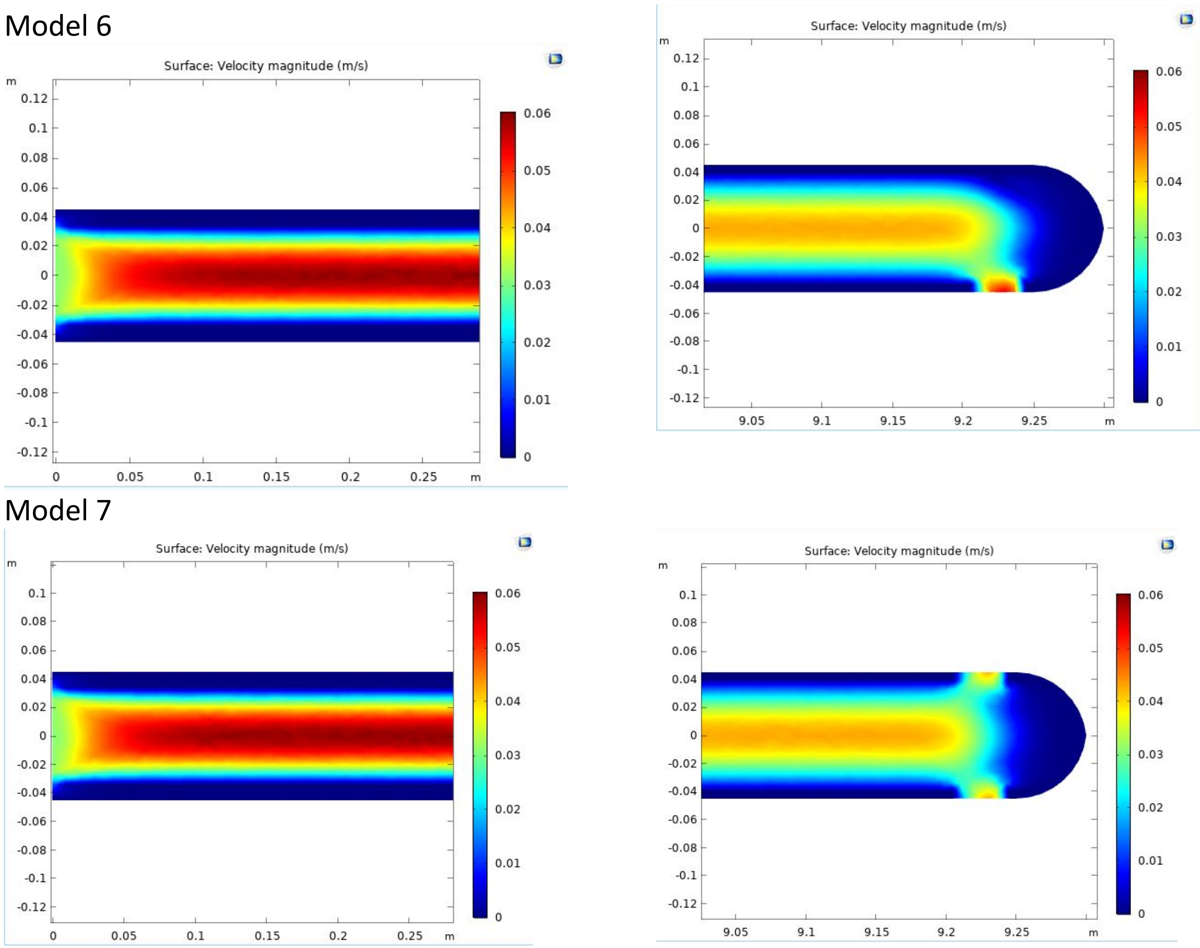


Fig. 7. Velocity Distribution of Model 3, 6 and 7

Figure 7 shows the result of flow velocity for Model 3, 6, and 7 in the start and end of the lance tube. The three models are different in their number of the nozzle. From the figure, we can see that model 3 has a big difference from model 6 and 7 in term of their velocity. Model 3 has a lower velocity compared to model 6 and 7. So, here we can see that the number of the nozzle also can affect their velocity distribution.

4. Conclusions

In this study, the lance tube soot-blower models were designed, constructed and analysed in term of its thermal performance computationally. The analysis provided us with the information of lance tube efficiency based on the thickness, nozzle diameter and the number of nozzle holes. The most efficient model is the Model 6 with three joint lance tube (3 thickness tube), (11mm (3m long), 7mm (3m long), 5mm (3.2m long)). The most efficient nozzle diameter and the hole was 30mm and 3 nozzle hole.

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